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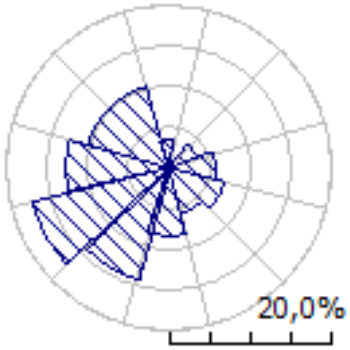
Long-term Variability of the Wind Speed over Land, in Coastal and in Marine Areas

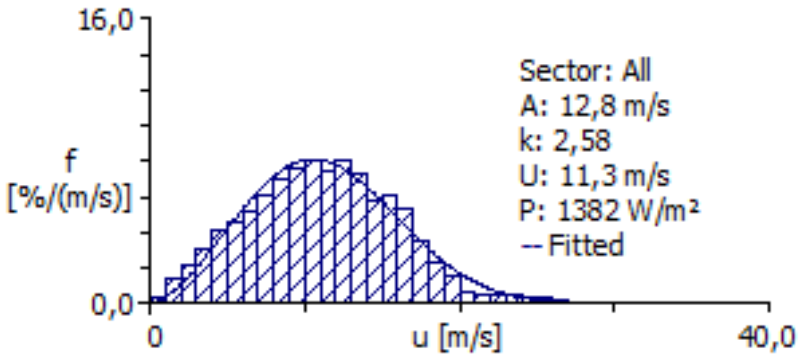
Sven-Erik Gryning[1],
Ekaterina Batchvarova[1,2]
Rogier Floors[1], Alfredo Peña[1]

[1]DTU Wind Energy, Technical University of Denmark
[2]National Institute of Meteorology and Hydrology, Bulgaria

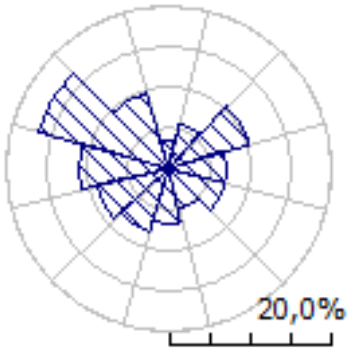
Outline.

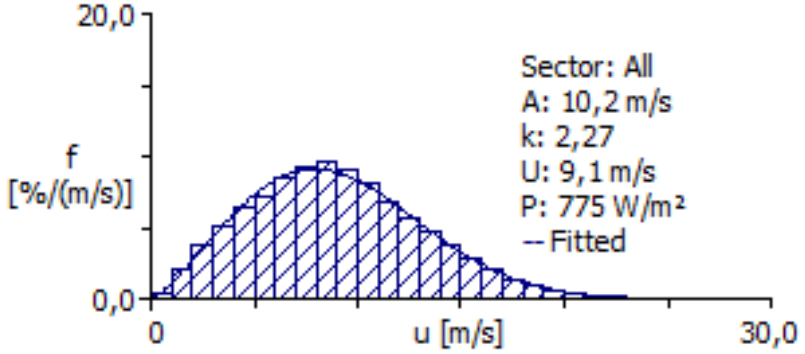
- Lidar Measurements
- Sensitivity to CNR (Carrier to Noise Ratio)
- Profile of Weibull distribution parameters (land, coastal and marine)



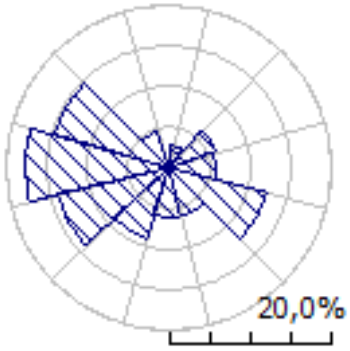


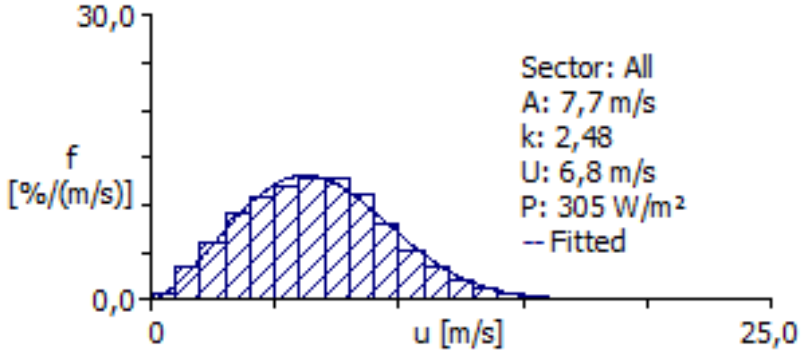
FINO3



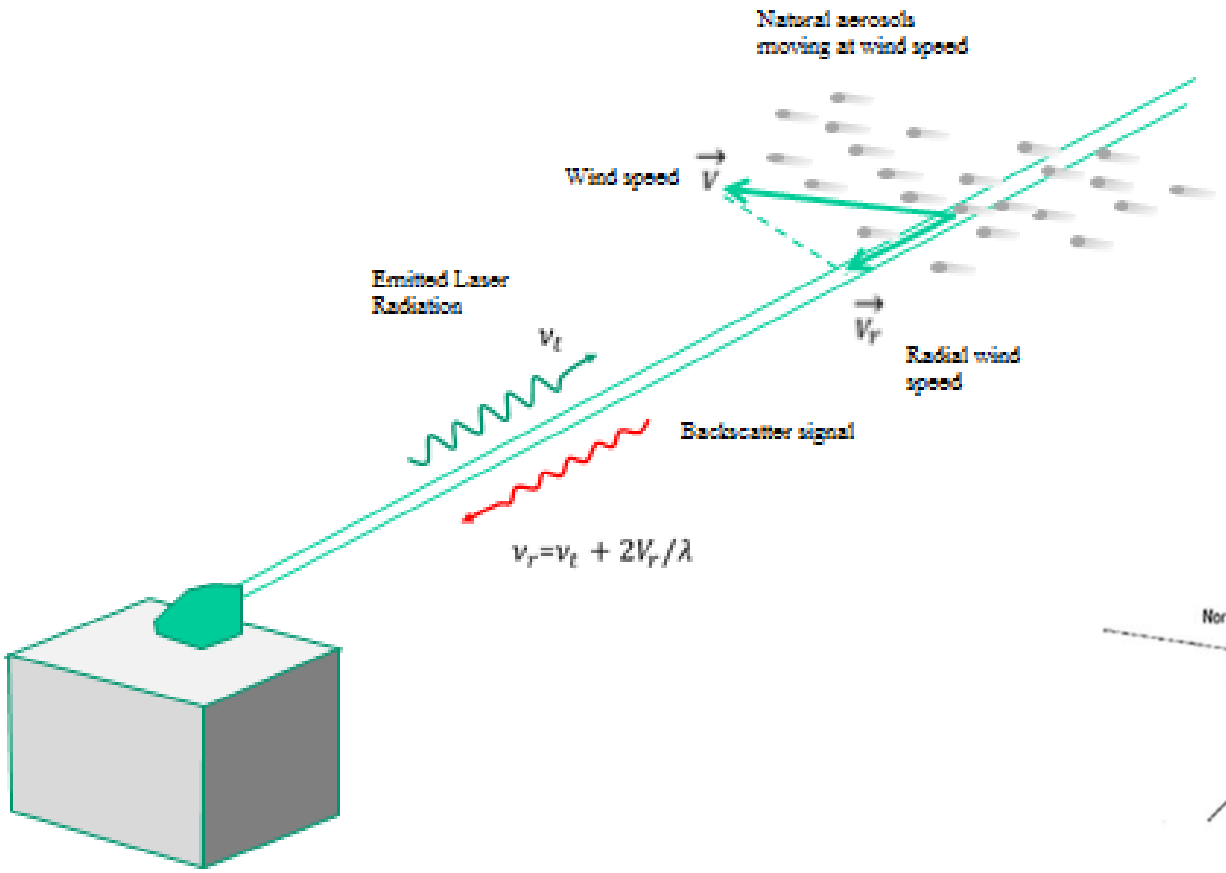


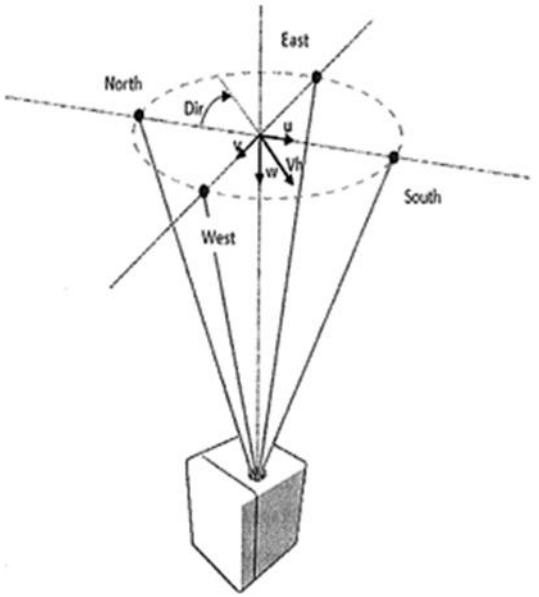
Coastal



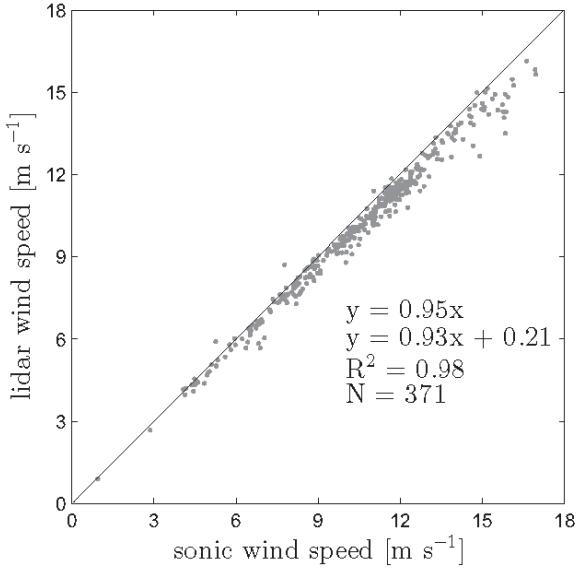


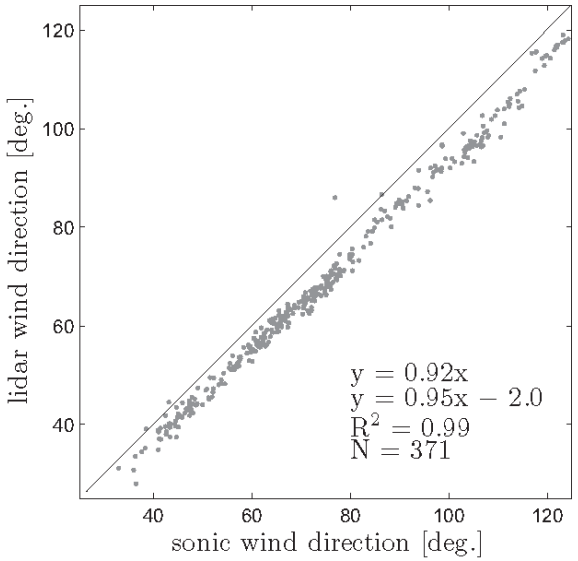
Hamburg


Natural aerosols
moving at wind speed
Wind speed $\vec{V}$
Emitted Laser
Radiation
v_t
$\vec{V_r}$
Radial wind
speed
Backscatter signal
$v_r = v_t + 2V_r/\lambda$

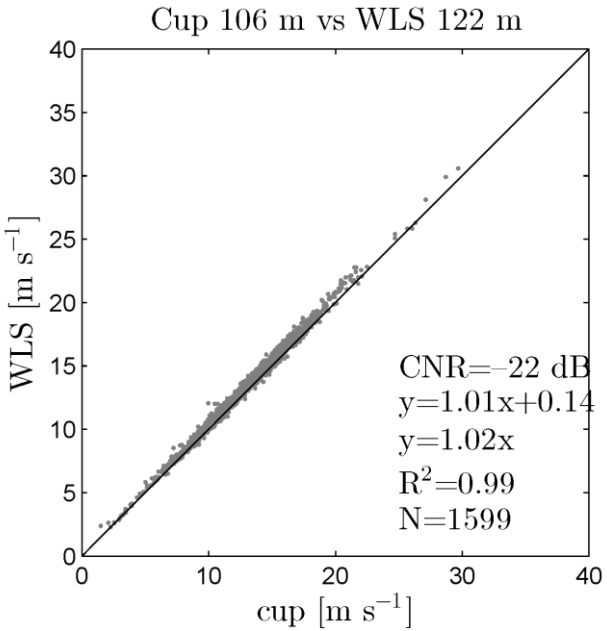

East
North
Dir
u
v
w
Vh
South
West

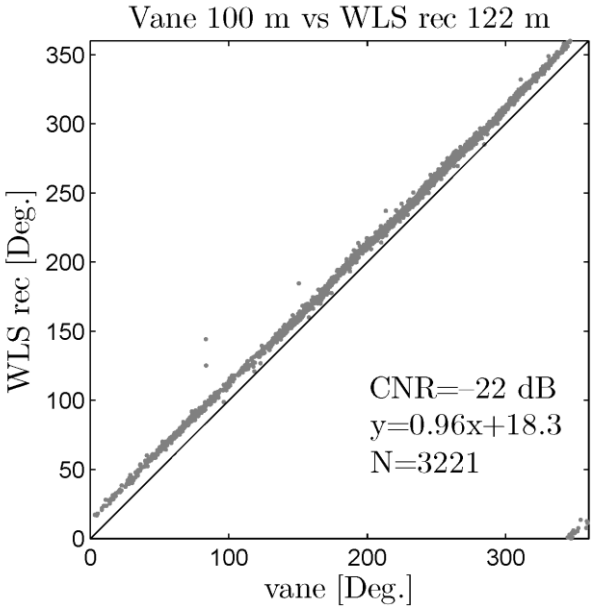
Comparison lidar cups/vanes





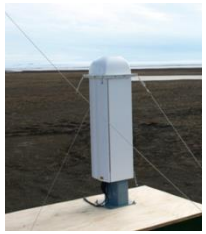
Høvsøre coastal

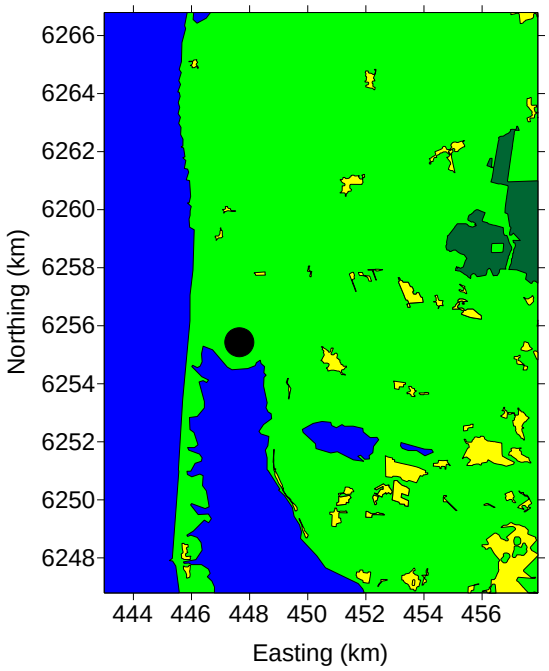




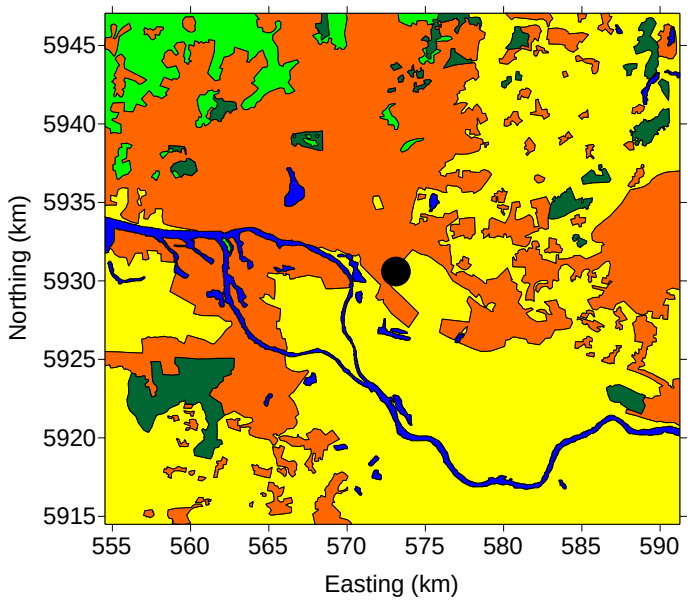
Fino3 marine

Tall Wind project

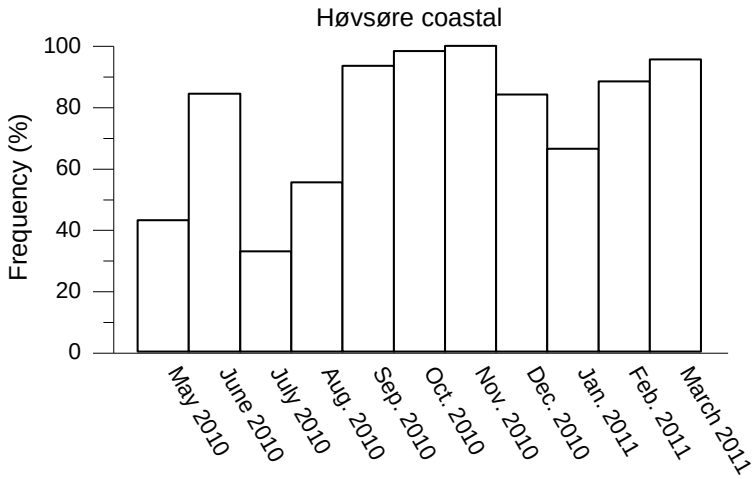


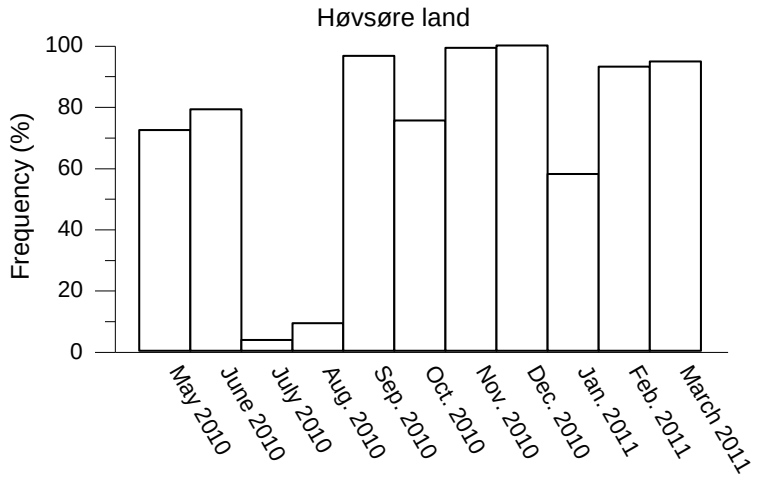


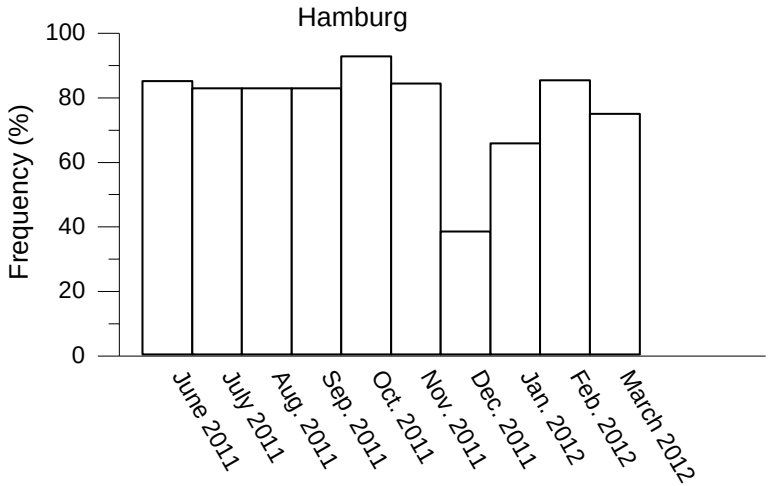
Høvsøre



Hamburg


Høvsøre coastal
Frequency (%)
0
20
40
60
80
100
May 2010
June 2010
July 2010
Aug. 2010
Sep. 2010
Oct. 2010
Nov. 2010
Dec. 2010
Jan. 2011
Feb. 2011
March 2011


Høvsøre land
Frequency (%)
0
20
40
60
80
100
May 2010
June 2010
July 2010
Aug. 2010
Sep. 2010
Oct. 2010
Nov. 2010
Dec. 2010
Jan. 2011
Feb. 2011
March 2011


Hamburg
Frequency (%)
0
20
40
60
80
100
June 2011
July 2011
Aug. 2011
Sep. 2011
Oct. 2011
Nov. 2011
Dec. 2011
Jan. 2012
Feb. 2012
March 2012

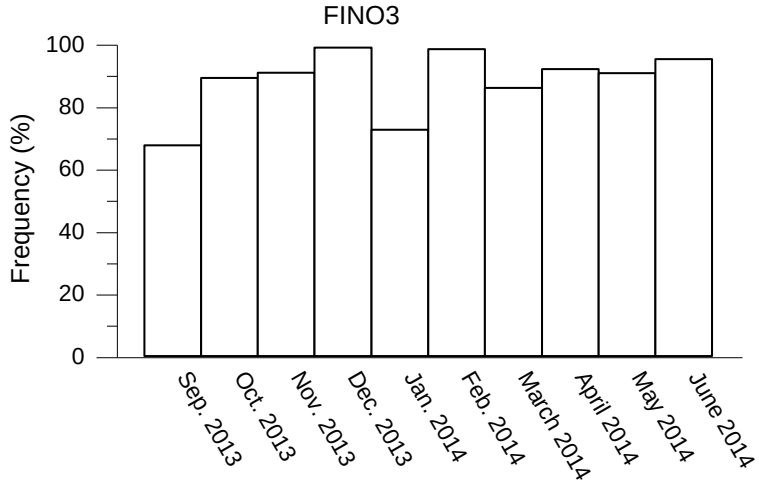
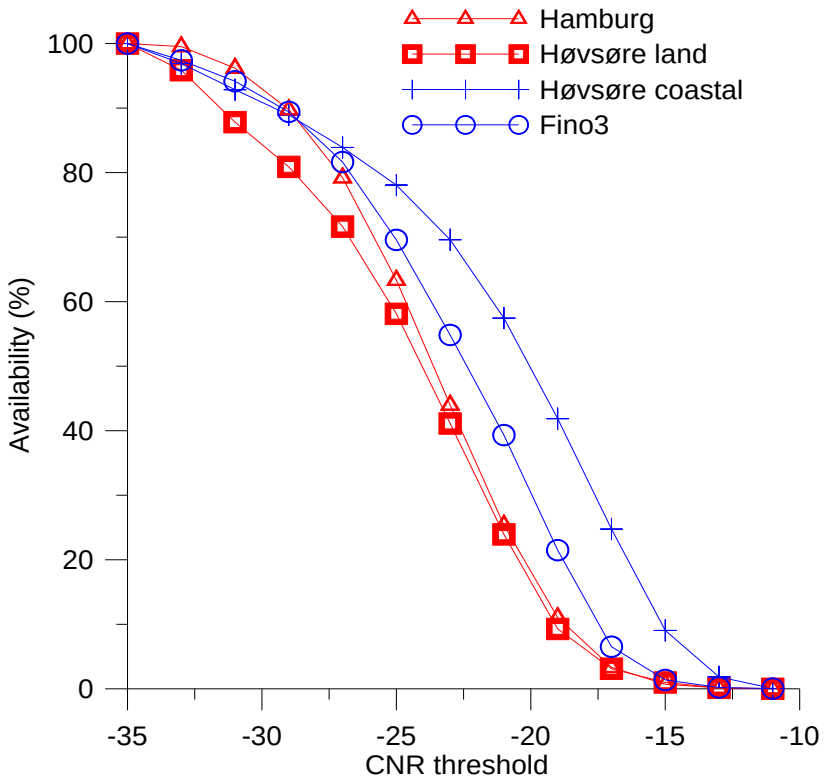

FINO3
Frequency (%)
0
20
40
60
80
100
Sep. 2013
Oct. 2013
Nov. 2013
Dec. 2013
Jan. 2014
Feb. 2014
March 2014
April 2014
May 2014
June 2014

Table 1 Number of measurements and measuring periods at each site. The numbers in brackets represent the number of wind lidar measurements relative to the total number of cup anemometer measurements.

Site	Wind lidar 100m/600m	Wind lidar and cup anemometer measurements; concurrent and full profiles up to 600 m	Cup anemometer	Period
Høvsøre-land	9885/8876 (84%)/(75%)	8754 (74%)	11758	25 April 2010 – 31 March 2011
Høvsøre-coastal	12618/11616 (73%)/(67%)	11383 (66%)	17377	
Hamburg	34692/27504 (88%)/(70%)	26403 (67%)	39374	15 June 2011 – 23 March 2012
Fino3	40685/34487 (100%)/(85%)	32425 (80%)	40541	29 August 2013– 26 June 2014

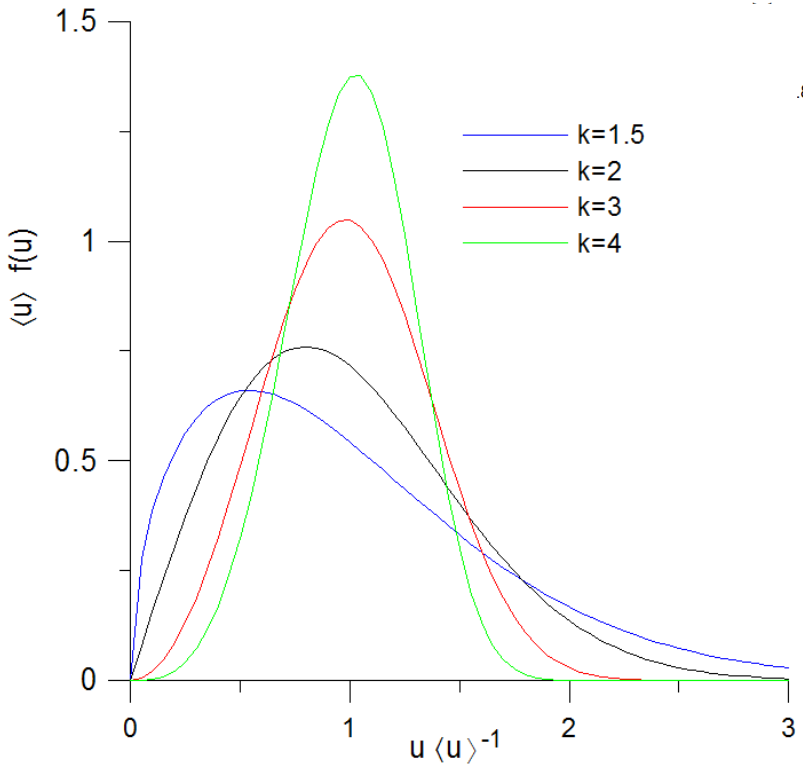
Data availability



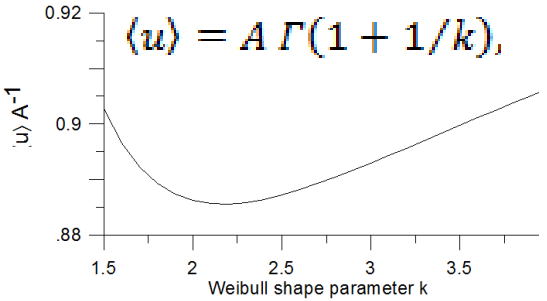
Weibull distribution

$$f(u) = \frac{k}{A}\left(\frac{u}{A}\right)^{k-1} \exp\left(-\left(\frac{u}{A}\right)^{k}\right)$$

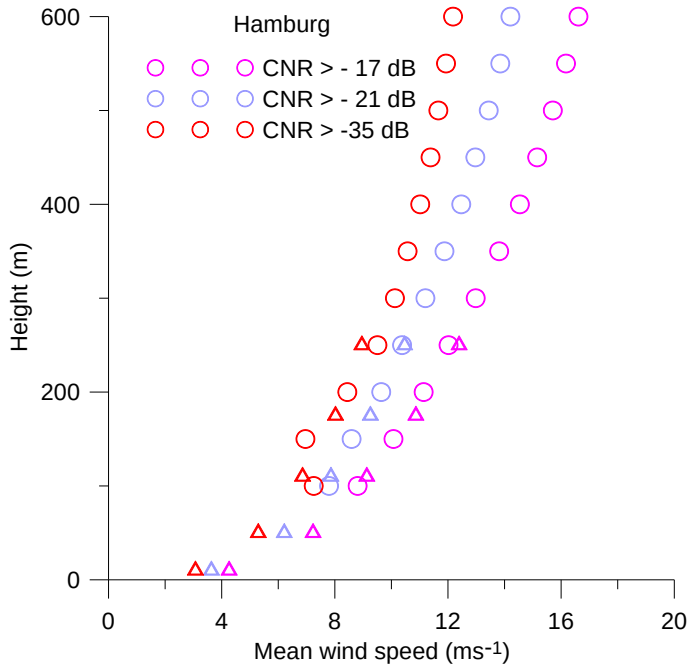
$f(u)$	the probability density function
u	Wind speed
$\langle u \rangle$	Mean wind speed
A	Scale factor
k	Shape factor

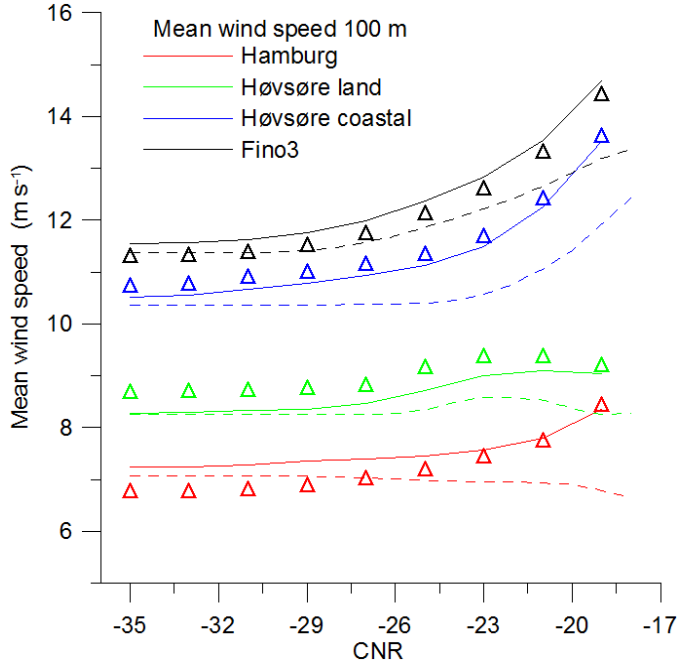


$$\langle u \rangle = A\,\Gamma(1 + 1/k),$$



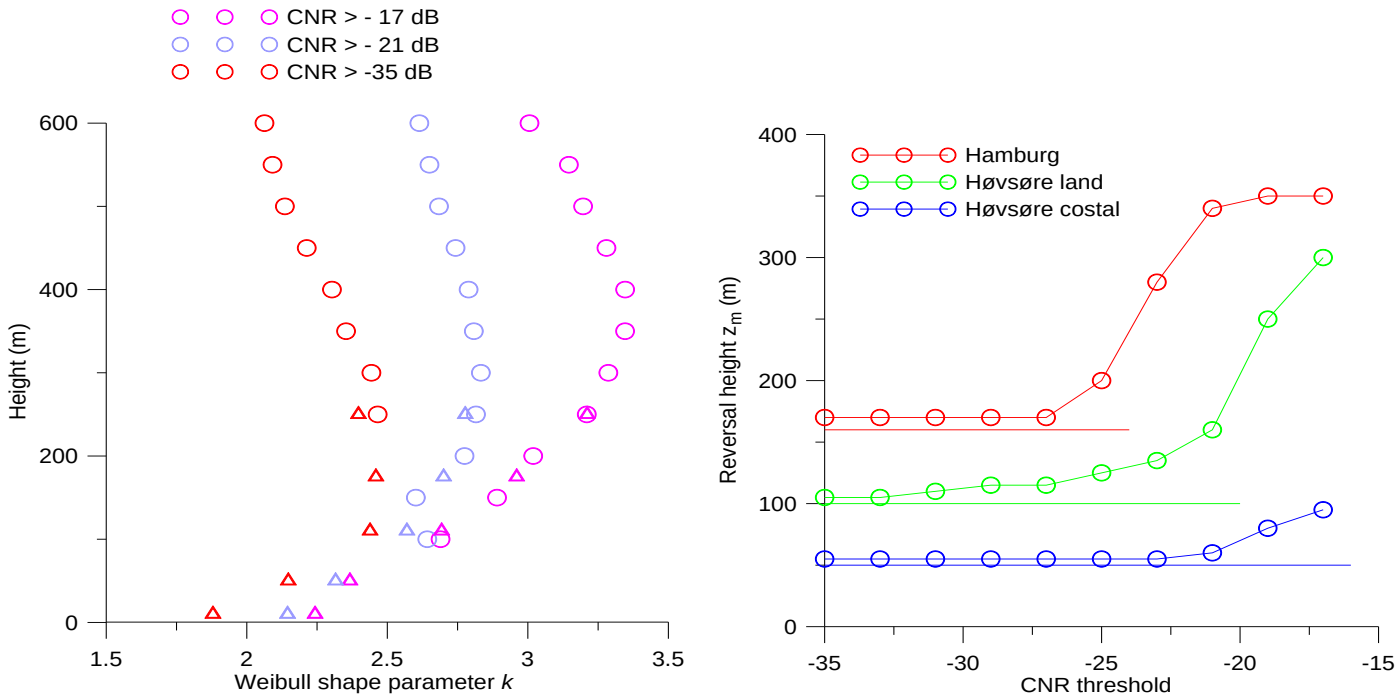
Mean wind speed - sensitivity to CNR





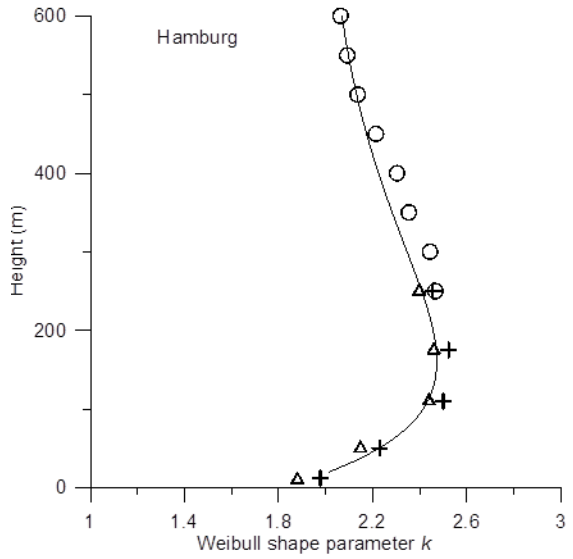
Left: the wind profile at Hamburg; circles represent observations by the wind lidar and triangles from cup anemometers.
Right: mean wind speed at 100 m as function of the CNR when full profiles up to 600 m are used. The full lines are wind lidar measurements, triangles concurrent wind speed from the cup anemometer. The dashed lines represent the CNR dependency when only the measurements at 100 m are used (no height filter).

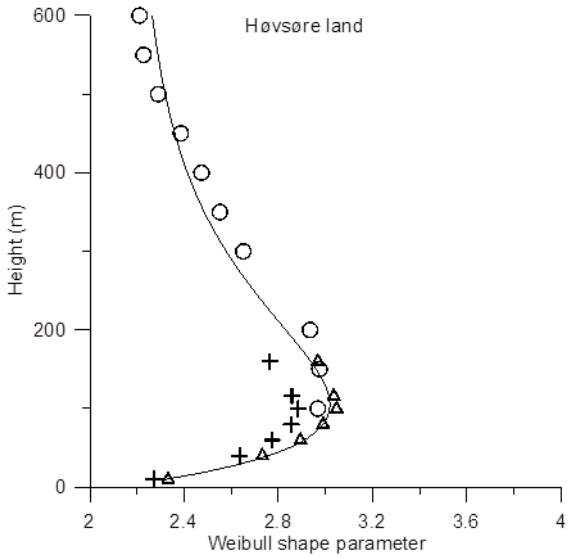
Reversal height – sensitivity to CNR

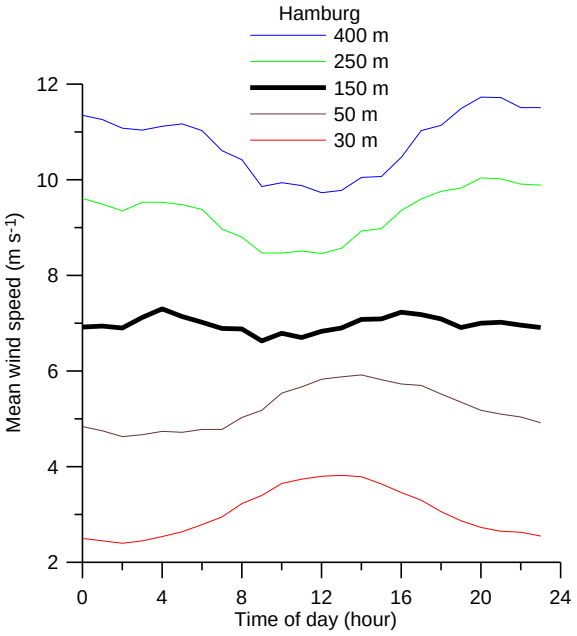


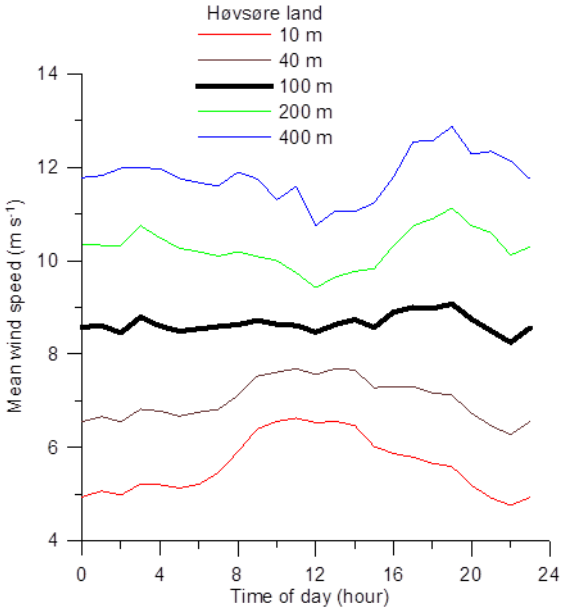
Generally good agreement between mast (triangles) and lidar (circles) for estimates of k. It is especially visible at Hamburg because of the height of the mast – illustrated here.

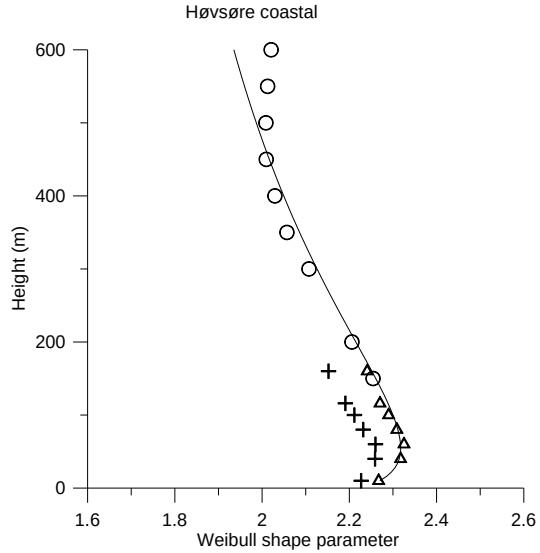
Full line parametrization suggested by Gryning et al. (2014)

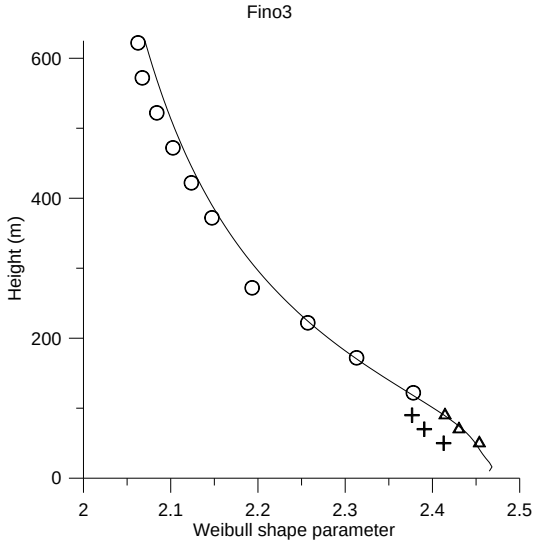


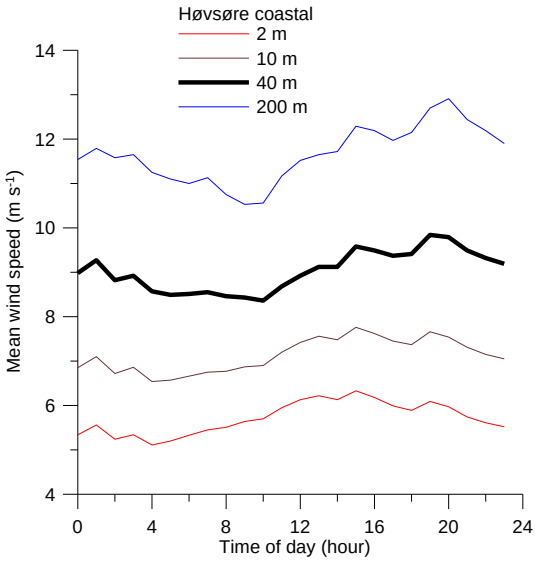


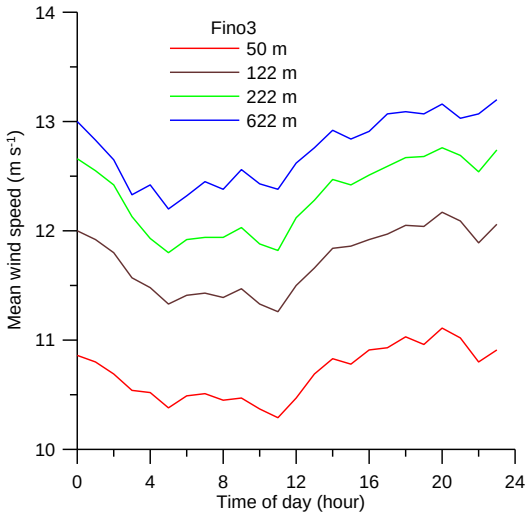





Høvsøre coastal
Height (m)
600
400
200
0
1.6
1.8
2
2.2
2.4
2.6
Weibull shape parameter


Fino3
Height (m)
600
400
200
0
2
2.1
2.2
2.3
2.4
2.5
Weibull shape parameter


Høvsøre coastal
2 m
10 m
40 m
200 m
Mean wind speed (m s-1)
14
12
10
8
6
4
0
4
8
12
16
20
24
Time of day (hour)

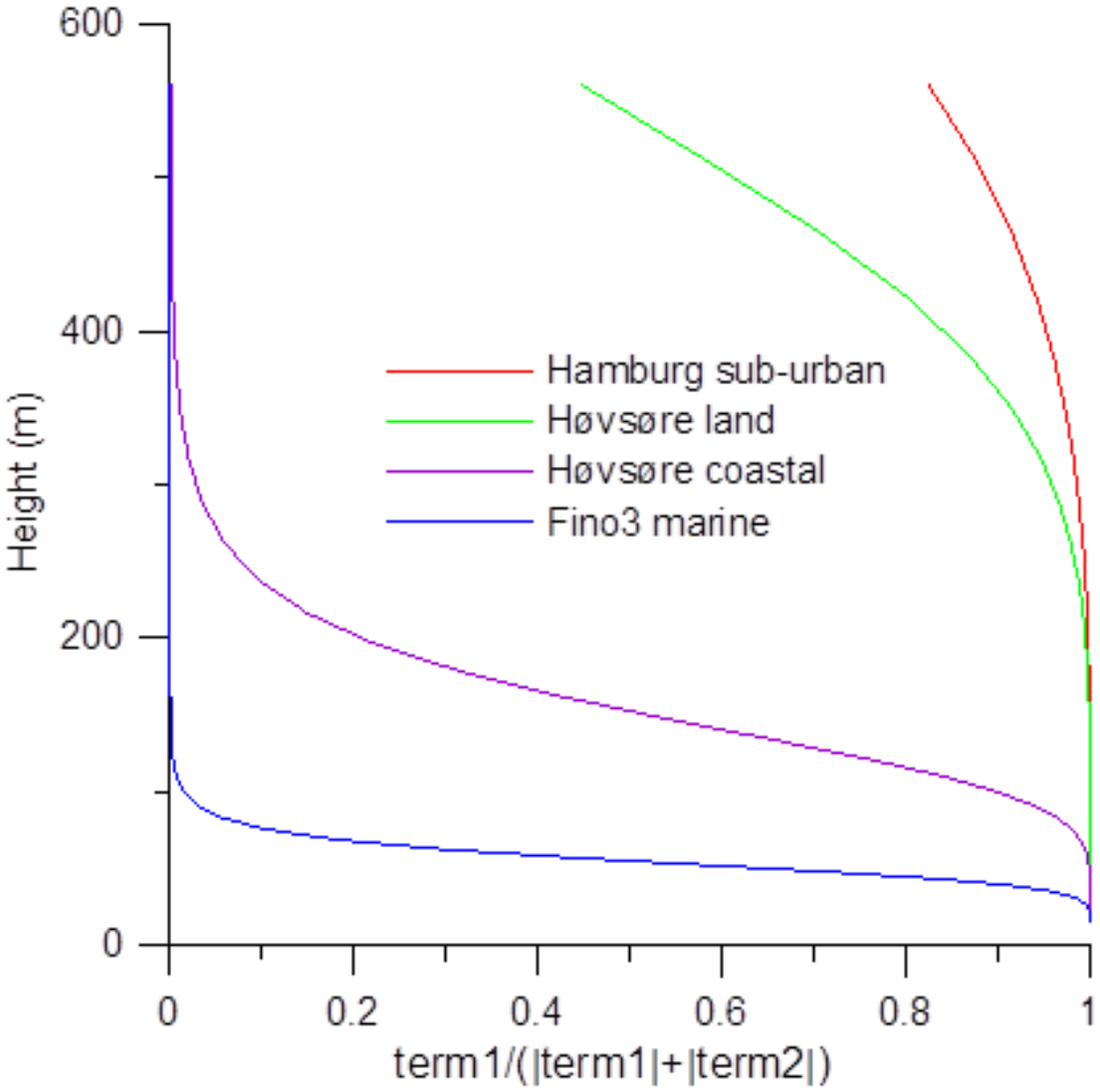

Fino3
50 m
122 m
222 m
622 m
Mean wind speed (m s-1)
14
13
12
11
10
0
4
8
12
16
20
24
Time of day (hour)

Wieringa (1989): $k = k_s + c_k(z - z_s)\exp\left(-\frac{z - z_s}{z_r - z_s}\right)$

Gryning et al. (2014)

$$k = k_s + c\,\frac{z - z_s}{z_r - z_s}\exp\left(-\frac{z - z_s}{z_r - z_s}\right) - (k_s - k_t)\exp\left(-\frac{z_t - z_s}{z - z_s}\right) \quad .$$

where k_s is the value of the shape parameter at the height z_s near the ground, z_r is the height of the shape parameter maximum (reversal height) and k_t is related to the synoptic value at height z_t.


600
400
200
0
Height (m)
Hamburg sub-urban
Høvsøre land
Høvsøre coastal
Fino3 marine
0
0.2
0.4
0.6
0.8
1
term1/(|term1|+|term2|)


Thanks
for your
attention